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APPLICATION FOR UNITED STATES LETTERS PATENT

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TITLE:	POWER STEERING PUMP HAVING ELECTRONIC BYPASS CONTROL
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**POWER STEERING PUMP HAVING ELECTRONIC BYPASS CONTROL  
RELATED APPLICATIONS**

**[0001]** The present patent document claims the benefit of the filing date under 35 U.S.C. §119(e) of Provisional U.S. Patent Application Serial No. 60/407,918, filed September 3, 2002, which is hereby incorporated by reference.

**TECHNICAL FIELD OF THE INVENTION**

**[0002]** This invention relates to a power steering pump wherein the fluid output is controlled by recycling a portion of the pumped fluid through a bypass port within the pump. More particularly, this invention relates to such power steering pump that includes a valve for controlling the size of the inlet to the bypass port.

**BACKGROUND OF THE INVENTION**

**[0003]** A power steering system of an automotive vehicle comprises a pump for providing hydraulic fluid under pressure. A typical power steering pump comprises a rotor having retractable vanes and rotating within a cam chamber. During operation, hydraulic fluid is drawn into the cam chamber from a fluid suction passage and pumped out under pressure to a fluid discharge port. The rotor is driven by the engine through a belt and pulley. As the speed of the engine increases, the volume of fluid pumped by the rotor also increases, and exceeds the volume required by the power steering system for optimum operation. The output from the pump is maintained at an optimum value by recycling a portion of the pumped fluid through a bypass port in the pump housing, so that pumped fluid is diverted from the outlet and returned to the suction passage. At low engine speeds, the bypass port is closed so that the entire volume of pumped fluid is outputted from the pump. However, at higher engine speeds, the bypass port is open for recycling as much as 90% of the pumped fluid.

**[0004]** United States Patent No. 5,887,612, issued Bleitz et al. in 1999, shows a mechanical valve for opening and closing a fluid bypass port to regulate the output from the pump. For this purpose, the housing defines a bore that communicates with a fluid discharge port from the pumping chamber and with the fluid bypass port. The outlet from the pump is located at one end of the bore and comprises a constricted passage to limit fluid output. Within the bore, a flow control valve slides to open and close the bypass port. The valve is biased in the closed position by a spring. During operation, particularly at higher engine speeds, the increased fluid volume acts upon the valve to contract the spring and open the bypass port, thereby diverting excess fluid from the outlet and recycling fluid through the bypass port.

**[0005]** Because of the restrictive outlet, the pump maintains a relatively constant output volume. Since the output is restricted, the excess fluid tends to push the spring-biased valve into the fully open position at higher engine speeds. Under certain conditions, it is desired to increase the output from the pump to improve performance of this steering system. It is known to provide a variable volume power steering pump wherein the size of the cam chamber is varied. During operation, the volume of pumped fluid is regulated by adjusting the cam chamber, so that a bypass port is not needed or provided. However, mechanisms for controlling the size of the cam chamber are complicated and require additional in-pump components and controls.

**[0006]** Therefore, a need exists for a power steering pump having a variable output, in which a portion of the pumped fluid is recycled through a bypass within the pump, and further in which the portion through the bypass is controlled to obtain a desired output from the pump.

## **BRIEF SUMMARY OF THE INVENTION**

**[0007]** In accordance with this invention, a power steering pump comprises a housing defining a bore having an axis, a fluid discharge port communicating with the bore at a first axial location, and fluid bypass port communicating with the bore at a second axial location. A flow control valve is slideably received in the bore and regulates the inlet for admitting fluid to the fluid bypass port. In accordance with this invention, electrical means are provided for sliding the flow control valve to vary the size of the inlet to the fluid discharge port and thereby increases or decrease fluid flow to the fluid bypass port, to adjust the output from the pump.

**[0008]** In one aspect of this invention, the pump includes a solenoid assembly that comprises a plunger that is connected to the flow control valve and is responsive to an applied electromagnetic field. An electromagnetic coil is provided outside the bore for applying an electromagnetic field to actuate the plunger. The position of the flow control valve depends upon the magnitude of the applied electromagnetic field, which in turn is regulated by the flow of current to the electromagnetic coil. By controlling electrical current to the electromagnetic coil, the size of the inlet to the bypass port is adjusted to control the proportion of fluid recycled through the bypass port. In this manner, the output from the pump may be electronically controlled to optimize performance depending upon driving conditions.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0009]** This invention will be further described with reference to the following drawings wherein:

**[0010]** Fig. 1 is a cross-sectional view, partially in schematic, of a power steering pump in accordance with this invention and showing a flow control valve in an open bypass position; and

**[0011]** Fig. 2 is a cross-sectional view of a portion of a power steering pump in Fig. 1, showing the elements thereof in a bypass closed position.

#### **DETAILED DESCRIPTION OF THE INVENTION**

**[0012]** In accordance with a preferred embodiment of this invention, referring to Fig. 1 and 2, there is depicted a power steering pump 10 for supplying pressurized fluid for a power steering system of an automotive vehicle. Pump 10 comprises a housing 12, preferably formed of aluminum alloy. Housing 12 contains pumping element, showing schematically, that include a rotor 14 that propels retractable vane 16 within a cam chamber 18. Housing 12 defines a fluid discharge port 20 that carries fluid under pressure from cam chamber 18, as indicated by arrow 22. The housing also defines a suction passage, indicated by arrow 24, for delivering fluid to cam chamber 18. During operation, rotor 14 is driven by the automotive engine via a belt and pulley arrangement. Fluid is pumped under pressure to discharge port 20 and exits through an outlet 27 in adapter 26, as output 28. Adapter 26 is connected through tubing to a rotary valve and steering gear of the power steering system. Fluid is returned to the pump through a return line (not shown) connected to suction passage 24 and is, in turn, drawn into cam chamber 18.

**[0013]** In accordance with this invention, the volume of output 28 from the pump is controlled by recycling a portion of the pumped fluid through a bypass port 30 to suction passage 24, as indicated by arrow 32. For this purpose, a bore 34 is provided in housing 12 and has a central axis 36. In the embodiment depicted in the Figs., bore 34 extends partially through the housing and includes an open end adjacent outlet 27. Bore 34 also communicates with discharge port 20 at a first axial location and with bypass port 30 at a second axial location that is axially spaced from the first location. In this embodiment, fluid discharge port 20 is located nearer the

open end of bore 34 relative to bypass port 30. Alternately, the passages within the housing may be configured so that the bypass port is nearer the bore open end than the fluid discharge port.

**[0014]** Fluid to bypass port 30 is controlled by a flow control valve assembly that includes a flow control valve 38 slideably received in sleeve 40 inserted in bore 34. Sleeve 40 comprises openings 42 and a circumferential groove 44 in fluid communication with fluid discharge port 20 and also comprises openings 46 and circumferential groove 48 in fluid communication with fluid bypass port 30. Valve 38 comprises openings 52 and circumferential groove 54 that communicate with openings 42 in sleeve 40, and 38 also includes openings 56 and a circumferential groove 58 adapted for communicating with openings 46 in sleeve 40. A central axial fluid passage 50 communicates with outlet passages 27. Valve 38 slides between a fully open position depicted in Fig. 1 and a closed position depicted in Fig. 2. During operation, fluid from fluid discharge port 20 is distributed by grooves 44 to flow through openings 42 into groove 54 and through opening 52 into central passage 50, and from central passage 50 through outlet 27. It is pointed out that groove 54 is axially widened, and that valve 38 includes multiple openings 52 that are axially spaced to provide continuous fluid communication between fluid discharge port 20 and central passage 50 despite movement of valve 38 between the fully open and closed positions. Moreover, during operation, when valve 38 is open, for example, in the fully open position depicted in Fig. 1, fluid flows from central passage 50 through openings 46 and groove 58 of valve 38, and thereafter through openings 56 and groove 48 to bypass port 30. This permits an excess portion of the pumped fluid to be recycled through bypass port 30 to control the output from the pump. In the closed position shown in Fig. 2, valve 38 slides to axially displace openings 56

relative to openings 46 in sleeve 40, where the circumferential surface of valve 38 closes the openings 46 in sleeve 40 to prevent fluid flow to bypass port 30. Thus, in this embodiment, openings 46 and 56 cooperate to define the inlet to fluid bypass port 30. It is an advantage of this invention that the position of valve 38 maybe varied between the fully open and the closed position to vary the size of the inlet to increase or decrease fluid flow to the fluid bypass port and thereby decrease or increase, respectively, the volume of pump output 28.

**[0015]** In accordance with this invention, valve 38 is opened and closed by a solenoid assembly 60 that includes an electrical coil 62 for generating an electrical field. Coil 62 is disposed about a conduit extension 64 that is connected at one end to sleeve 40 and at the opposite end to adaptor 26, using O-ring 66 and 68 to seal the connections. A coil spring 70 is disposed between valve 38 and adaptor 26 within extension 64 and biases the valve in the open position. Electrical connections to coil 62 are made by terminal 72 protected by a shield 74. A threaded connector 76 is provided for mounting to the housing 12. It is pointed out that the elements, including valve 38, sleeve 40, coil 62, and adaptor 26, are assembled to form a single flow control assembly that may be readily installed into housing 12 as a single component. Further, in the event that a repair of pump 10 is necessary, the flow control assembly may be readily removed and replaced, thereby reducing the time and expense required for such repair.

**[0016]** In the depicted embodiment, prior to operation, valve 38 is biased in the fully open position shown in Fig. 1 by coil spring 70. In the fully open position depicted in Fig. 1, pumped fluid from the pumping elements, including rotors 14, vanes 26 and cam chamber 18, deliver pumped fluid to fluid discharge port 20. The pumped fluid flows through openings 42 in sleeve 40 and openings 52 in valve 38

into central passage 50. A portion of the fluid flows through central passage 50 and extension 64 and outlet 27 to provide the output 28 for the pump. Excess fluid flows from passage 50 through the inlet formed by openings 56 in valve 38 and openings 46 in sleeve 40 into bypass port 30 and are combined with returning fluid 24, thereby recycling the fluid within the pump.

**[0017]** During operation, rotor 14 is driven by the engine of an automotive vehicle by a belt and pulley arrangement. The pumping elements, including rotors 14, vanes 26 and cam chamber 18, are preferably sized so that, at low engine speeds, the volume of pumped fluid is equal to the desired output 28 of pump 10. Under these circumstances, it is desired that no portion of the pumped fluid be returned through bypass port 30. This is accomplished by positioning valve 38 to close bypass port 30 from fluid communication with fluid discharge port 20, as shown in Fig. 2. To close valve 38, terminal 72 are connected to an electrical power supply, and current is conducted through coil 62 to generate an electromagnetic field within extension 64. Valve 38 is preferably formed of steel or other suitable magnetizeable material and thus serves as the plunger for the solenoid assembly. Thus, valve 38 moves axially in response to the applied electrical field to the closed position shown in Fig. 2. The movement of valve 38 contracts spring 68. Fluid flows from fluid discharge port 20 through openings 42 in sleeve 40 and openings 52 in valve 38 into passage 50. With the valve in the closed position, the entire volume of fluid flows through passage 50 and outlet passage 27 and provides output 28 for the pump.

**[0018]** It is an advantage of this invention that the position of valve 38 may be adjusted to vary the size of the inlet to the bypass port and thereby control the pump output 28 to optimize performance to the power steering system for particular driving conditions. By way of example, an optimum pump output may be determined based



upon vehicle speed, steering wheel rate, and fluid pressure within the power steering system. For this purpose, a control module may be provided for regulating current to electromagnetic coil 62. The control module receives input, for example, for vehicle speed and steering signals, and determines an optimum system pressure or fluid volume using a look-up table or algorithm. The control module then regulates current to the electromagnetic coil 62 to adjust the position of the flow control valve. In this manner, the flow control valve may be moved to increase or decrease the size of the inlet to the bypass port and so increase or decrease the proportion of pumped fluid. Opening the valve increases flow fluid through the bypass port and decreases output 28, whereas closing the valve decreases flow to the bypass port and increases output 28. By making appropriate adjustments to the position of the flow control valve and thus to the size of the inlet to the fluid bypass port, an optimum output may be obtained for particular driving conditions.

**[0019]** Therefore, this invention provides a power steering pump wherein the flow control valve controls the inlet to the fluid bypass port and varies the size of the inlet to thereby regulate the volume of fluid flowing through the bypass port. This is in marked contrast to conventional pumps having mechanical valves that restrict flow through the outlet, thereby increasing pressure within the bore to fully open the valve and divert excess fluid to the bypass. The position of the flow control valve may be adjusted electronically by a solenoid assembly connected to the valve that opens and closes the valve in response to electric current to an electromagnetic coil. The solenoid assembly is readily mounted on the pump and connected to the electronic control system for the automotive vehicle. By adjusting the fluid volume through the bypass port, the flow control system with this invention permits the output of the power steering pump to be adjusted for a desired value.

**[0020]** In the described embodiment, the flow control valve was disposed within a sleeve and includes openings that cooperate with openings in the sleeve to define the inlet to the fluid bypass port. Alternately, the valve may open and close the opening of the fluid bypass port to regulate the size of the inlet without requiring a sleeve. Also, whereas the flow control valve in the described embodiment slides axially, in an alternate embodiment, the flow control valve may be rotated to open and close the inlet to the bypass port. This may be accomplished by a step motor or other suitable electronic actuator capable of varying the angular orientation of the valve.

**[0021]** While this invention has been described in terms of certain embodiment thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow.